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TOXICOLOGICAL SAFEGUARDS IN THE MANNED MARS MISSIONS

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ABSTRACT

Safeguards against toxic chemical exposures during manned Mars missions (MMMs) will be important for the maintenance of crew health and the accomplishment of mission objectives. Potential sources of toxicity include offgassing, thermodegradation or combustion of materials, metabolic products of crew members and escape of chemicals from containment. Toxic exposures during MMM's are of especially great concern because of their long duration. This would give toxins a long time to accumulate and a long time to exert their adverse effects. Other concerns regarding toxic exposures during MMMs are the long time that would be required for crew members to return to Earth for medical aid and the great cost of crew impairment.

Safeguards against introduction of excessive environmental toxins and against excessive crew exposure include proper materials selection in regards to offgassing, heat stability and flammability; proper containment of bulk chemicals, alarms warning of chemical release into the atmosphere, the wearing of protective clothing, goggles and masks, the use of fume hoods while handling toxic chemicals, and the availability of safe havens for crew members to take refuge in event of high levels of toxic chemical contamination of their living environment.

Decontamination of breathing atmospheres will probably be performed by the use of regenerable absorbents, catalytic oxidizers, and condensors. Spilled chemicals may, in some instances, be recovered by the use of vacuum pumps.

New spacecraft maximum allowable concentration (SMAC) limits will have to be established for potential contaminants during the MMMs. The following factors will be used in establishing these new limits: Duration of missions, simultaneous exposure to other contaminants, deconditioning of crew members after long periods of reduced gravity, and simultaneous exposure to ionizing radiation.

Atmospheric contaminant levels in all compartments of the transit spacecraft and Manned Mars Station (MMS) will be monitored at frequent

intervals with a real time analyzer. This analyzer will be highly automated, requiring minimal crew time and expertise. The atmospheric analyzer will find other usages during the MMMs such as analyzing Martian atmospheres and soils, exhaled breath and body fluids of crew members, and reaction products in chemical processing facilities.

INTRODUCTION

Safeguards against toxicological exposures will be an important factor in the maintenance of crew safety, health and well-being during the manned Mars missions (MMMs). As in current spaceflight missions, the greatest emphasis will be on controlling toxic contaminants in the breathing atmospheres. Skin, eye and oral toxicities will also be important concerns. Possible sources of toxic chemicals in the transit spacecraft and the Manned Mars Station (MMS) environments include: (1) Offgassing of non-metallic materials--a few examples of chemicals frequently seen during offgassing tests of various spaceflight hardware materials include acetaldehyde, acetone, methylethyl ketone, isopropyl alcohol, xylene, trichloroethane, toluene, methane and Freon 113. These same chemicals are also often seen in air bottle samples taken from the crew quarters during Space Shuttle flights; (2) Metabolic products release by crew members including carbon dioxide, carbon monoxide, pyruvic acid, methane and skatole; (3) Escape from containment of stored chemicals--as from heat exchangers, fire extinguishers, tissue fixatives or reactants from chemical processing facilities; and (4) Thermomoderation or combustion of electric wire insulations or other materials.

Toxic contamination of the transit spacecraft or the MMS environment would probably have greater consequences than it would during missions of shorter duration for the following reasons:

Contaminant Accumulation

The transit spacecraft will require about nine months to travel from Earth to Mars and an equal time to return. The MMS will probably exist for many years. Due to the sparseness of the Martian atmosphere, and its lack of oxygen, the MMS will have a closed environment, similar to that of the transit spacecraft vehicle. Therefore, atmospheric contaminants that were not adequately removed by an inside decontamination system in the MMS could accumulate to dangerous levels over long periods of time.

Extended Crew Exposure

The individual MMMs will probably be of 20 months or longer duration, including the time in transit to and from Mars. Continuous exposure to some chemical contaminants over a long period of time would probably cause harmful effects to crew members at levels that would be harmless after shorter periods of exposure.

Long Time to Return to Earth for Medical Aid

If a crew member were made ill from a toxic chemical exposure and could not be adequately treated at the MMS he would have to wait a long time before receiving medical care on Earth since he would probably have to wait until the tour of duty on Mars ended and then would have to travel for nine months to reach Earth.

Cost Impact of Crew Impairment

The many scientific experiments and observations to be performed along with survival in the harsh Martian environment will require high levels of mental alertness and physical stamina. Therefore, considering the high cost of a MMM, the cost impact of improper or incomplete performance of planned tasks or early termination of a mission would be very great.

SAFEGUARDS AGAINST ENVIRONMENTAL TOXICITY

Considering the above consequences of environmental toxicity to the MMM, adequate safeguards against toxic exposures will be quite important. Most of these safeguards are similar to those currently used. They will include the following:

Proper Materials Selection

Candidate materials selected for use in the interior linings, insulations and flight hardware of the transit spacecraft and the MMS will have to undergo extensive preflight testing and be proven to be of low toxicity potential before usage. Selection will include:

Minimal Offgassing Characteristics

Most plastic and other nonmetallic materials slowly release a number of chemical vapors into the atmosphere. This is called offgassing. The rate of offgassing is increased by reducing the atmospheric pressure. Materials that offgas excessive amounts of trace gas contaminants (TGCs) are not considered to be acceptable for spaceflight. Due to the long duration of the MMMs and the probability of atmospheric pressures in the transit spacecraft and MMS being less than the 14.7 psi used today, minimal offgassing requirements for materials to be used in habitable areas will probably be more stringent than those required for materials used in today's spacecraft.

<u>High Heat Stability and Low Flammability</u>

Thermodegradation or combustion of many commonly used synthetic materials produces carbon monoxide, hydrogen cyanide, hydrogen fluoride and many other highly toxic gases. It is likely that in association with reduced atmospheric pressures, the breathing atmospheres of the transit spacecraft and the MMS will be 28% oxygen or higher. This will greatly increase the chance of combustion of many materials. Therefore, high heat stability and low flammability will be very important criteria for selection of materials to be used in the MMMs.

<u>Containment of Bulk Chemicals</u>

High levels of containment of bulk chemicals will be extremely important, since they could cause high levels of toxicity within a short time following escape. Bulk chemicals will probably include heat exchangers, disinfectants, fire extinguishants, tissue preservatives, electrolytes in storage batteries, and chemicals used in various types of scientific experiments and chemical processing facilities. Paints, adhesives and ingredients for insulation foams, all containing volatile chemicals, might be used in constructing the MMS. Even very small leaks in a large chemical reservoir might cause the release of toxic quantities of chemical vapors into habitable areas, causing physical or mental impairment or adverse health effects on crew members.

In cases where bulk chemicals do present a toxicological hazard, double or triple containment will probably be required. An airtight storage cabinet would count as one level of containment. It must also be definitely established that materials used in the containment vessels, including valves and O rings, are compatible with the contained chemicals so they will not be eroded over longer periods of time. Pressure alarms may be set up in certain types of containers, giving warning of overpressurization or a sudden loss of pressure (indicating that a chemical had escaped).

Alarms Near Potential Sources of Chemical Release

The atmospheres near stored chemicals, especially near actively functioning systems such as heat exchangers or processing facilities, must be monitored with alarms that would immediately warn the crew members of an increase in the concentration of vapors of these chemicals. Auditory alarms that warn of the sudden release of aldehydes and ketones, aromatic hydrocarbons, and a wide range of other chemicals are currently available and are widely used in industry.

Wearing of Protective Clothing, Goggles, and Masks

Because of the seriousness of illness or injury resulting from contact with toxic chemicals during a MMM (see above), extraordinary care must be taken by crew members to avoid contact during handling or working near these chemicals. It should be remembered that many gaseous or liquid chemicals are readily absorbed into the bloodstream through the skin. Some caustic chemicals may cause long term or even permanent visual impairment upon direct contact with the eyes. Therefore, persons working with or around toxic chemicals should be required to wear goggles along with gloves and other protective clothing. If there is a risk of the release of noxious vapors, crew members should also either wear an oxygen or charcoal filter mask or have one immediately available.

Fume Hoods

When one is handling volatile and toxic chemicals in certain processes such as infixing tissues with glutaraldehyde, the use of a fume hood, preferably a closed one with glove ports, will be important. A fume hood used within the closed environment of the MMS or transport vehicle would vent its outflow air through charcoal or another absorbent that could remove any contaminant vapors. It would be similar to the ones designed for the Spacelab.

A Safe Haven

In both the transit spacecraft and in the MMS, there must be a safe haven, that can be closed off from the principle living area. Here the crew members could take refuge in the event of a chemical spill or if toxic substances were released through thermodegradation. The safe haven should be able to support all of the crew members until the principal living area could be decontaminated.

MEANS OF DECONTAMINATION DURING THE MANNED MARS MISSION

As mentioned above, the toxic chemical vapors will be continuously released into the habitable areas of the transit spacecraft and the MMS through offgassing and crew respiration. In addition, large amounts of toxic vapors may enter the atmosphere unexpectedly through leakage of stored chemicals or thermodegradation of construction materials. Therefore, continuous removal of TGCs will be essential for maintaining a clean, safe environment. Equipment for the efficient removal of high concentrations of noxious vapors or quantities of spilled liquids or solids will also be necessary. Systems for accomplishing these tasks include:

Regenerable Absorbent Air Filters

The air filters to be used during the MMMs should effectively absorb a wide range of chemical vapors, including those of relatively low molecular weight. They should also be regenerable in order to minimize bulk and weight requirements. Most TGCs could be absorbed by charcoal, molecular sieves or other absorbents and then desorbed by heating at reduced atmospheric pressures. TGCs not removed by normal charcoal or molecular sieves may be removed by chemically treated charcoals.

Catalytic Oxidation

Catalytic oxidation, using platinum or other catalysts at ambient or elevated temperatures, may be useful in oxidizing carbon monoxide and other organic chemicals to carbon dioxide. Incomplete oxidation of many chemicals, however, may produce even more toxic products, so this should be avoided.

Condensation

Vapors of many alcohols and other water soluble substances will be condensed, along with water, by the duhumidifier system. These and other vapors may also be condensed in a cold trap, perhaps downstream from the duhumidifier. The cold outdoor climate of Mars at most times could provide very adequate cold for a cold trap.

Vacuum Pumps

Larger quantities of spilled liquids could, in many instances, be recovered with a vacuum pump. The Martian gravity would make this moot, however, since a liquid would fall to the floor and spread out, rather than float around in the air as a large sphere as would be the case in a microgravity environment.

CONSIDERATION FOR TOXIC CONTAMINANT EXPOSURE LIMITS

The design of toxic contaminant control systems for the MMM breathing atmospheres will be centered around keeping TGC's below designated SMAC* limits. Previously established SMAC limnits for space ventures of shorter duration will probably be revised for the MMMs. Factors to be considered in establishing these revised SMAC limits will include: (1) The anticipated maximum length of the MMM tours of duty; (2) The potential for simultaneous exposure to other toxic vapors; (3) The expected effect of physical deconditioning during the MMMs which could reduce one's resistance to the effects of certain toxic exposure; and (4) The expected effect of simultaneous radiation exposures which could enhance some types of toxicity.

A REAL TIME ONBOARD ANALYZER

Description

One essential item for toxicological control during MMMs will be a real time atmospheric analyzer, both in the transit spacecraft and in the MMS. This analyzer will probably be a more advanced design of the gas chromatograph/mass spectrometer (GC/MS) planned for the Space Station. It should be capable of monitoring atmospheric TGC's at fairly frequent intervals (at least several times daily) and should be capable of taking air samples through vent lines from each room or compartment that is used for human habitation. It will be highly automated, requiring minimal crew time and will not require a highly trained analytical chemist.

Other Usages Besides Atmospheric Analysis

The real time analyzer will probably find other applications besides analyzing atmospheres during the MMMs. It may be used in the analysis of the Martian atmospheres, soils and mineral deposits. It could also be used in health maintenance and in physiological experiments, analyzing body fluids and the exhaled breath of crew members for different metabolites. Still another usage might be the monitoring of reaction products produced in chemical processing facilities, seeing how well chemical reactions would precede in this new environment.

*Spacecraft Maximum Allowable Concentration